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# Impact of frequency of alignment of physical and information system inventories on out of stocks: A simulation study

Paras M. Agrawal *, Ramesh Sharda

*Spears School of Business, Oklahoma State University, Institute for Research in Information Systems, Stillwater, OK 74078, USA*

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ABSTRACT

Inaccuracy in the information system inventory as compared to the physical inventory may lead to out of stocks. Inaccuracy may occur for many reasons, a principal one being random losses such as theft. One way to reduce this inaccuracy is to adjust the inventory information in the systems at some regular frequency. Such alignments are quite expensive in practice. Thus how often to align the two inventories is the focus of this research. A simulation model is employed to investigate the effect of such loss defined by the stock loss parameter ($\lambda$) and the frequent alignment of physical and information system inventories on the stockout ($S_{\mathrm{out}}$) and average inventory ($I$). A term to be called the effective value of stock loss parameter is introduced to signify the effect of frequency of alignment ($f$) on $S_{\mathrm{out}}$. The results derived in this study provide a powerful tool in the hands of an inventory manager. It has been noted that, so far as stockout is concerned, by selecting a moderate value of alignment frequency ($f$), the effective value of stock loss parameter ($\lambda_e$) can be reduced to $\sim \lambda/f$. The accuracy of $S_{\mathrm{out}}$ and $I$ values across a number of runs in the simulation studies, sensitivity of $S_{\mathrm{out}}$ and $I$ on various parameters and the nature of stochastic demand distribution, and application of these results with or without deployment of RFID to reduce the loss due to stockout are also discussed. The results, verified under various scenarios, indicate that there is a significant reduction in stockout loss when the alignment is done monthly vs. annually, but it does not add much value beyond a monthly check.


## 1. Introduction

One of the important roles of the management in a retail industry is to optimize the stockout and inventory levels. The significance of the loss due to stockout can be perceived from the fact that the average out of stocks (OOS) rate is about 8% (Corsten and Gruen, 2003). The OOS situation not only puts the retailers at a major loss but the suppliers also suffer its heavy impact. After not finding a desired item in stock, 11% of the consumers do not purchase the item, 16% delay the purchase, 21% substitute with the same brand, 22% substitute with different brand, and 31% buy at another store (Corsten and Gruen, 2003).

It is important to note that among various causes of OOS, store forecasting and store ordering amounts to 51% of the total OOS (Corsten and Gruen, 2003). Store ordering and forecasting in turn very much depend on the accuracy of the inventory information. The Auto-ID center at MIT finds that on average the inventory record for one-out-of-four stock keeping units (SKUs) in the store does not agree to the actual stock by six or more items (Kang and Gershwin, 2005). Qualitatively, one can very well perceive that due to inaccuracy in the inventory record, the items cannot be appropriately ordered in a timely fashion. If the physical (PH) inventory is lower than the information system (IS) inventory then there would be a delay in the ordering that would result into the OOS.

One of the major sources of a lower value of PH inventory is the stock loss or shrinkage due to theft by shoppers, vendors, and employees. A study conducted by ECR Europe reveals that the shrinkage in a fast moving consumer goods sector is 2.41% of the whole turnover value of the sector, and theft accounts for two thirds of shrinkage (28% internal thefts and 38% external thefts) (Rekik et al., 2009).

Kang and Gershwin (2005) consider the inventory inaccuracy due to the stock loss not reflected in the IS inventory. In their simulation study, they compute explicit values of stockout and average inventory for different ordering parameters, demand variables, and lead time. For demand, they take a combination of demand for purchase having normal distribution and a demand for loss described by a Poisson distribution. They showed that even a small amount of recurring stock loss not reflected in the IS inventory can disrupt the replenishment process such that revenue loss due to stockout could exceed the stock losses themselves. For a typical case, they demonstrate that a stockout value of ~17% decreases to less than 1% when Auto-ID is used to align

* Corresponding author.
*E-mail address:* parasagrawal@hotmail.com (P.M. Agrawal).

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IS inventory with the PH inventory at the end of each period. They also show that through RFID technology one can achieve the best stockout-inventory compromise (the lowest inventory for any given stockout), and the benefit of inventory accuracy provided by RFID becomes greater as the desired level of stockout becomes smaller.

We come across a number of studies dealing with RFID technology (for reviews, e.g., see Alani et al., 2009; Angeles, 2005; Nambiar, 2009; Weier, 2009). Wal-Mart jump started the RFID by a June 2003 mandate that its top 100 suppliers attach tags on pallets and cases shipped to its stores in the Dallas, Texas region. Despite the reluctance of a large number of retailers to adopt the RFID technology due to initial investment in installing RFID readers and associated software and the recurring cost of RFID tags and other associated expenditures, the RFID technology is being hailed as one of greatest contributions of the century (Mehrjerdi., 2009). To derive benefits, studies related with cost effectiveness (e.g., Ustundag and Tanyas, 2009; Miragliotta et al., 2009; de Kok et al., 2008; Bottani and Rizzi, 2008), and new innovative ideas of incorporating the technology (e.g., Heim et al., 2009; Delen et al., 2007; Amini et al., 2007; Hardgrave et al., 2006; Chongwatpol and Sharda, 2009) would prove valuable. The search of innovative ways of reducing the lost sales due to OOS with the help of RFID is one of the areas of interest.

We not only need innovative ways of employing RFID but we also need to optimize the manner of using the data for operations. For example, in exploring the possibility of reducing the OOS situation by aligning the IS inventory with the PH inventory we need to optimize the frequency of this alignment as each alignment costs significant human time even with RFID, though it is a fraction of the time needed manually (Hardgrave, 2009; Hardgrave et al., 2009). As mentioned earlier, Kang and Gershwin (2005) have shown that the alignment of PH and IS inventories at the end of each period leads to a quantum jump in the reduction of the OOS. They also reported the amount of reduction in the stockout when such an alignment is made twice within a total duration of 365 periods. There is a need to extend their results over a wider range of frequencies and simulation parameters to study the impact of frequency of alignment on OOS.

The purpose of this research is to advance our understanding regarding the optimization of the frequency of counting the physical inventory by investigating the relationship between the stockout ($S_{\text{out}}$) and the frequency ($f$) of alignment of PH and IS inventories under various conditions of demand, ordering, and shrinkage, when the inventory record inaccuracy is due to stock loss only. As the knowledge of average inventory ($I$) is valuable in making any decision for the optimization, we shall also study the variation in $I$ with $f$. The possibility of finding an optimized value of $f$ would be explored by some numerical examples. For many cases, we would see that there is a significant reduction of stockout when the alignment is done monthly vs. annually, but the additional advantage of going from monthly to daily is very small. Other related aspects such as sensitivity of $S_{\text{out}}$ and $I$ on various parameters, the effective value of the stock loss parameter as a function of frequency ($f$), and the accuracy of computed values of $S_{\text{out}}$ and $I$ in the simulation studies are also studied. We describe the interesting new result showing a relationship between an effective stock loss and the frequency of alignment of physical and system inventory. As far as stockout is concerned, by selecting a moderate value of alignment frequency ($f$), the effective value of stock loss parameter ($\lambda_e$) can be reduced to $\sim \lambda/f$.

We first review some of the literature in the next section. In Section 3, the simulation model developed for this study is described. The results are then presented and discussed in Section 4. Finally, the conclusions are described in the last section.

## 2. Literature review

As early as more than half a century back, Rinehart (1960) highlighted the impact of discrepancies between IS and PH inventories on a supply operation. Iglehart and Morey (1972) investigated the proper frequency and depth of inventory counts to minimize the total cost when there is likelihood of a discrepancy between the IS and PH inventories. More recently, Sandoh and Shimamoto (2001) proposed a mathematical model to provide an optimal frequency for periodical inventory taking to detect a gap between the IS and PH inventories in a retail store. Fleisch and Tellkamp (2005) examined the relationship between inventory inaccuracy and performance in a three-echelon retail supply chain. In the base model, they align the PH and IS inventories when the out-of-stock situation is detected. In the modified model, IS inventory is aligned to PH inventory at the end of each period. By comparing the results of these two models for different parameters signifying theft, unsaleables, and the process quality they show that elimination of inventory inaccuracy can lead to the reduction in supply chain costs as well as stockout. They also find that among the three factors studied, the inaccuracy caused by theft makes the biggest impact on supply chain performance. They further point out that the RFID technology has the potential to enhance the inventory accuracy.

Kok and Shang (2007) investigated an inspection adjusted base-stock policy in which the manager performs an inspection if the inventory recorded is less than a threshold level. By comparing the cost given by different policies, they also arrived at the value of inventory information, which may be provided by RFID. deHoratius and Raman (2008) examined nearly 370, 000 inventory records of one retailer having annual sales of approximately $10 billion. They found 65% records to be inaccurate. As regards the impact of this inaccuracy, in the last section of their paper, deHoratius and Raman (2008) write, *"We provide evidence that the problem of record inaccuracy is substantial in magnitude in the retail context. And the resulting lost sales can amount to a considerable portion of firm profit."* Gumrukcu et al. (2008) employed the cycle counting method (Young and Nie, 1992; Muller, 2003; Piasecki, 2003) using a simulation model in a two-echelon supply chain. Their results show that the correct application of cycle counting can lead to significant amount of saving for the supply chain. Sahin et al. (2008) and Sahin and Dallery (2009) considered the newsvendor type model to evaluate the economic impact of the inaccuracies in the inventory records.

Rekik et al.(2009) considered a store in which PH inventory is lower than the IS inventory due to theft. They compared three approaches: (a) neither RFID technology is employed nor the manager knows the errors occurring in the store, (b) RFID is not employed but the manager takes advantage of having knowledge of the errors, and (c) the advantage of a perfect RFID technology is taken. By comparing the three approaches they analyze the impact of the discrepancy in the PH and IS inventories due to theft and the value of RFID. Based on their quantitative analysis, they provided the optimal inventory policy for each approach.

Sethi (2010) observed that to address the problems related with the incomplete inventory information the classical inventory control approaches are inadequate and there is a need to develop new approaches. Thiel et al. (2010) proposed analytical results as well as simulation modeling to determine the impact of inventory inaccuracy on the quality of service. Using several simulations, they showed that loss in sale (stockout) is a non-monotone function of the inventory inaccuracy rate. This result is in sharp contrast with that of Kang and Gershwin (2005). The results of Kang and Gershwin reveal that stockout is a monotone function of the inaccuracy rate. It may be noted that Kang and Gershwin (2005) consider the inventory inaccuracy due to shrinkage (theft